

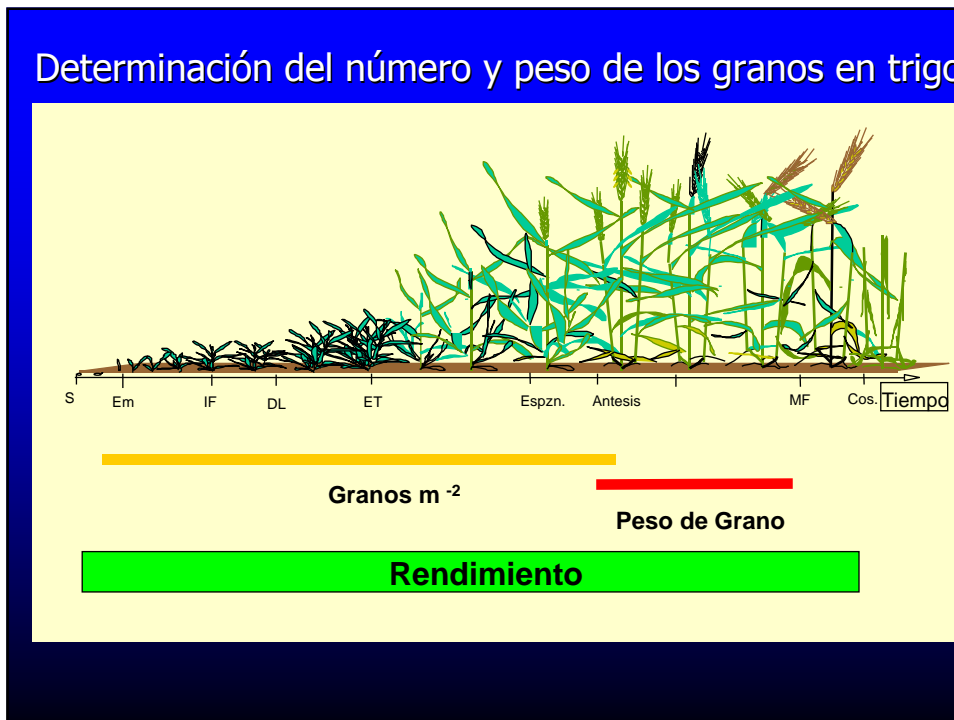

Red 110RT0394 **METRICE**
 Mejorar la eficiencia en el uso de insumos y el
 ajuste fenológico en cultivos de trigo y cebada
 Universidad Autónoma del Estado de México



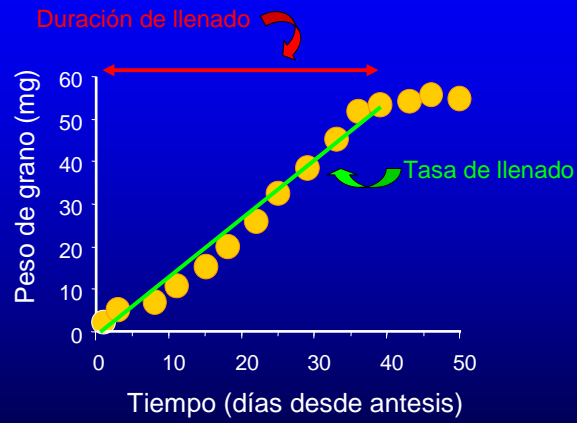
Crecimiento de los Granos: Fases e indicadores de sus Etapas

Daniel F. Calderini
 Universidad Austral de Chile

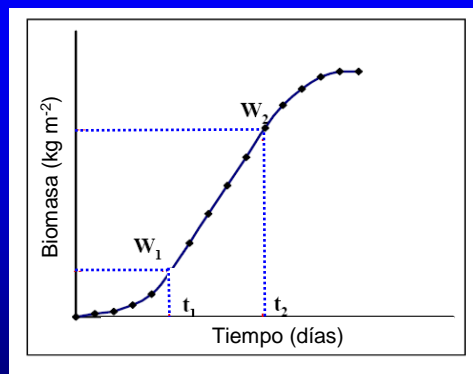

 Toluca, septiembre de 2011

Llenado de Granos



Aproximación Clásica al Crecimiento



$$\text{Biomasa } (W) = A + C / [1 + \exp(-B(t - M))]$$

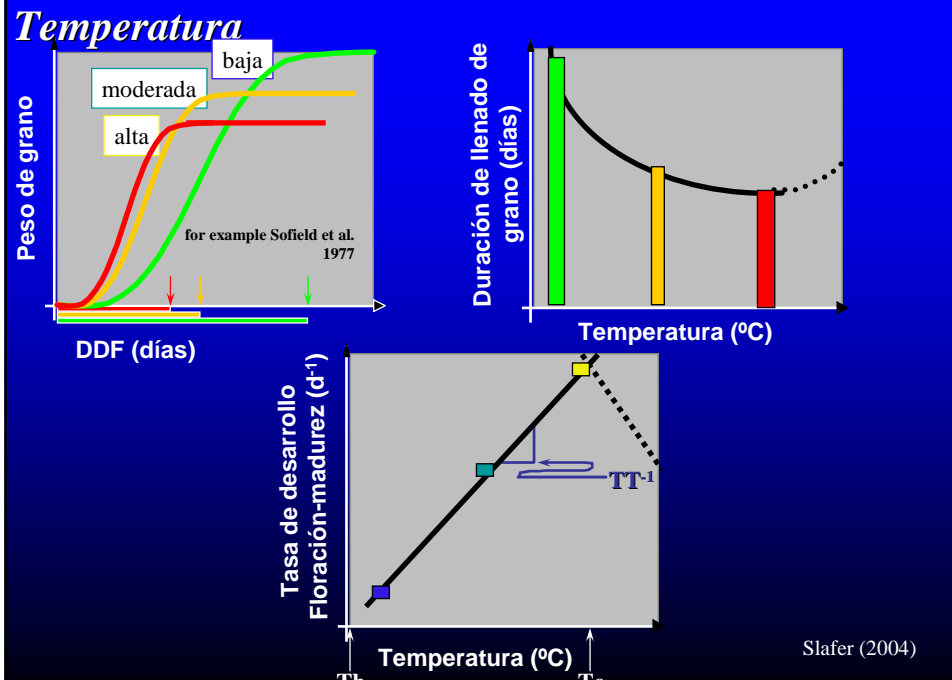
$$\text{Tasa de crecimiento (TC)} = dW/dt$$

Blackman (1919)

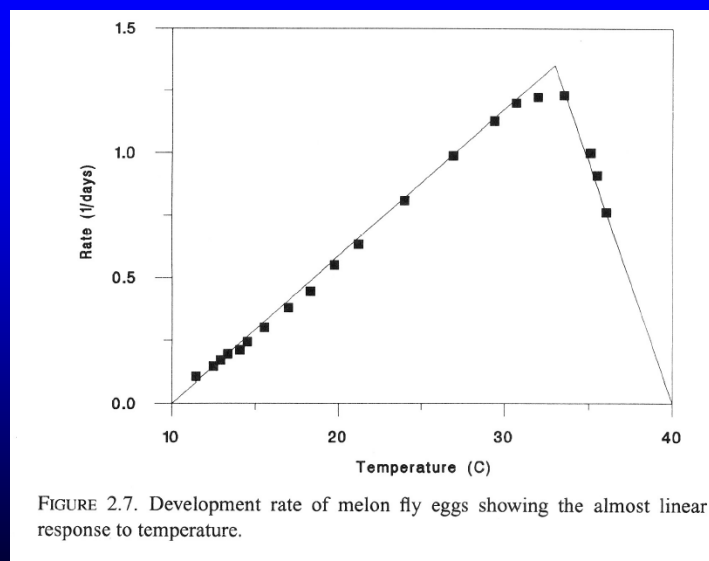
$$\text{Tasa de crecimiento relativo (TCR)} = 1/m \cdot dm/dt$$

Watson (1952)

Duración de la etapa floración-madurez fisiologica



Respuesta del desarrollo de insectos a la temperatura



Hall (2001)

Crop Responses to Environment

Calculo del Tiempo térmico

permite comparar el desarrollo de cultivos que crecen bajo regímenes térmicos diferentes, superando las debilidades inherentes en el uso de tiempo calendario

Para valores de temperatura entre T_b y T_{opt}

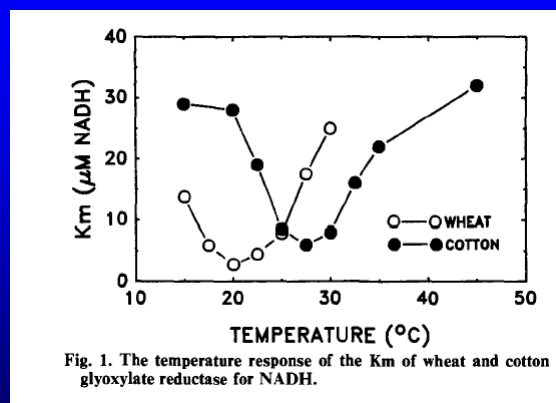
$$\text{Tiempo térmico (TT)} : \sum_{\text{dia} = i}^{\text{dia} = n} (T_d - T_b)$$

donde T_d es temperatura media diaria ($[\max + \min]/2$)

Se requieren tratamientos más complejos para situaciones en que $T^\circ > T_{opt}$ ó $T^\circ < T_b$ durante todo o parte del día.

Slafer (2004)

Temperatura y reacciones enzimáticas



Burke et al. (1988)
Agronomy Journal

Evolución de la temperatura a lo largo del día

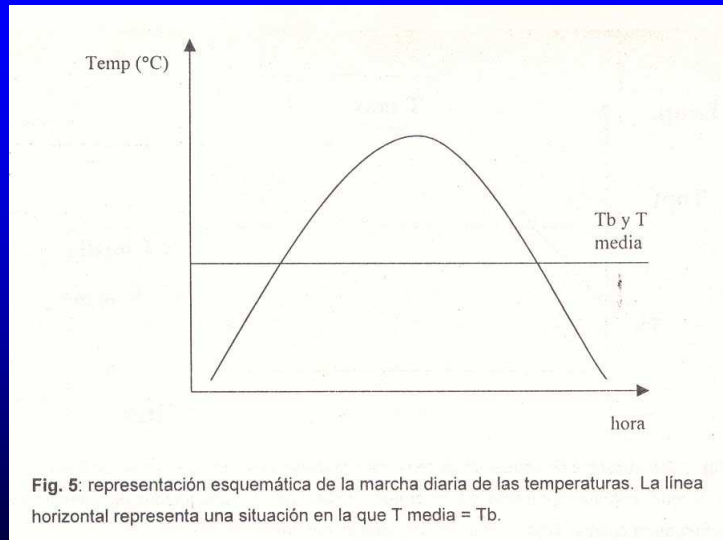
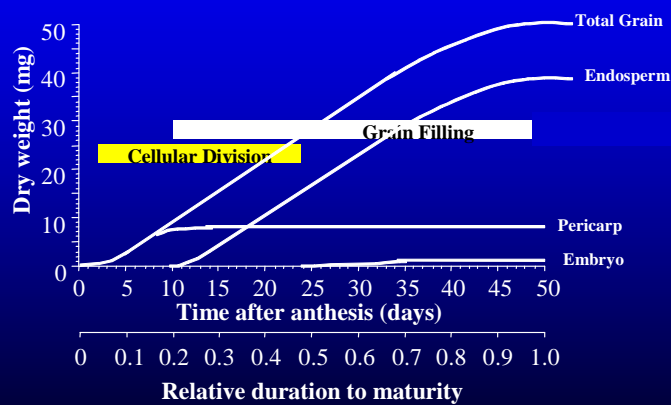


Fig. 5: representación esquemática de la marcha diaria de las temperaturas. La línea horizontal representa una situación en la que $T_{media} = T_b$.

Producción de Granos. Bases funcionales para su manejo (UBA)

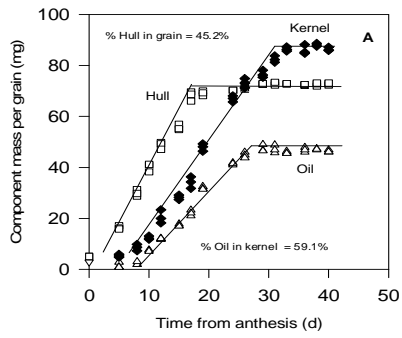
Pericarpio, Endosperma y Embrión durante el Crecimiento de Grano



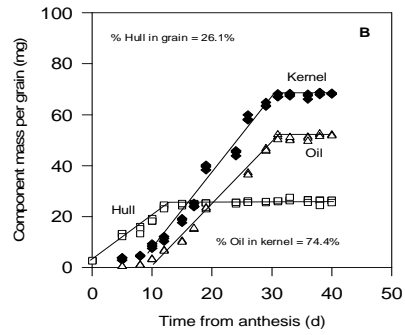
Savin. (1996)
PhD. Thesis



Pericarpio y Embrión en Granos de Girasol



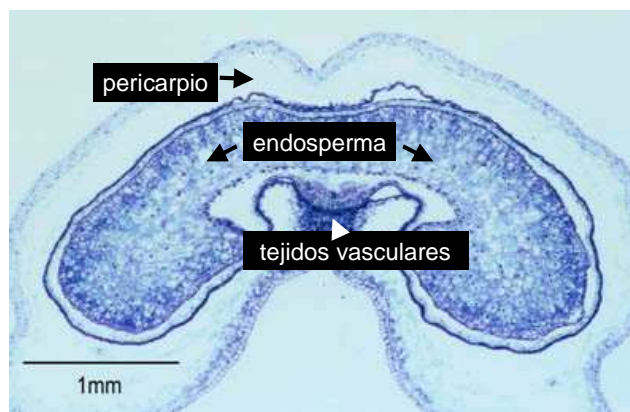
Variedad Confitera



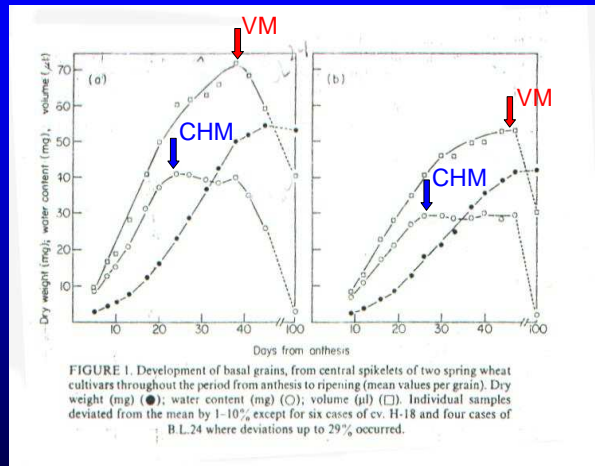
Híbrido para aceite

Mantese, 2001

Pericarpio y Endosperma del Grano en Trigo

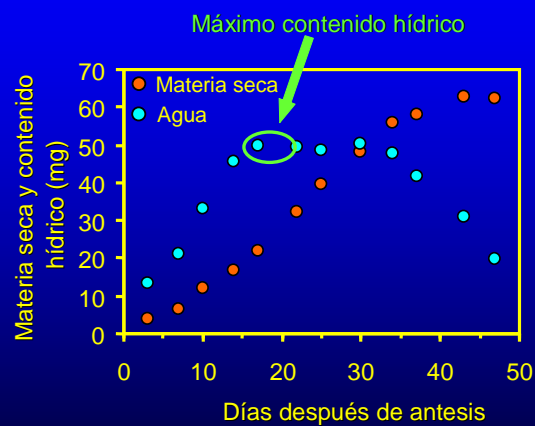


Peso Seco, Contenido Hídrico y Volumen de los Granos



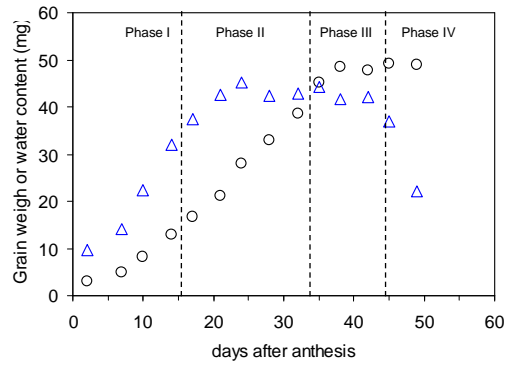
Millet & Pinthus (1984)
Journal of Cereal Science

Dinámica de la materia seca y el contenido hídrico de los granos

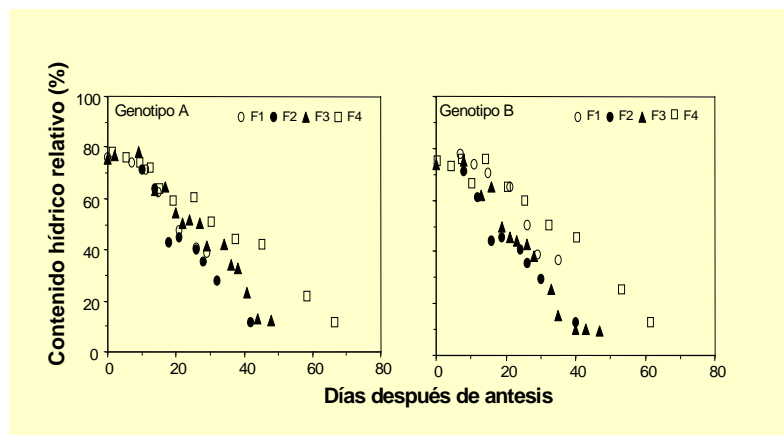


Lizana et al. (2010)
Journal of Experimental Botany

Fases del Crecimiento de los granos

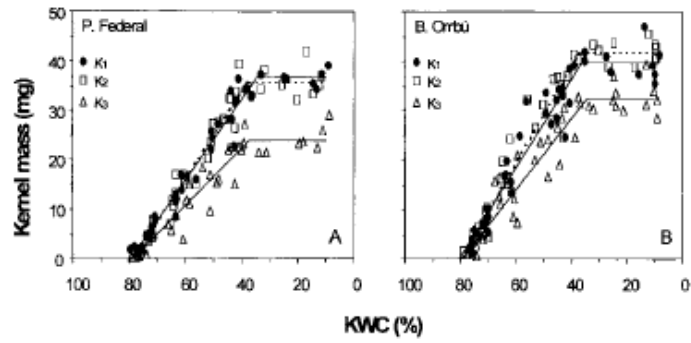


Contenido Hídrico de los Granos

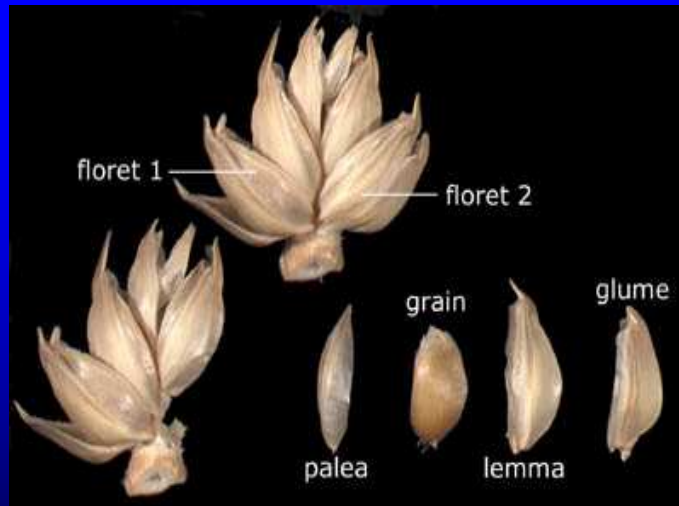


Calderini *et al.* (2000)
Agronomy Journal

Peso de Grano y Contenido Hídrico

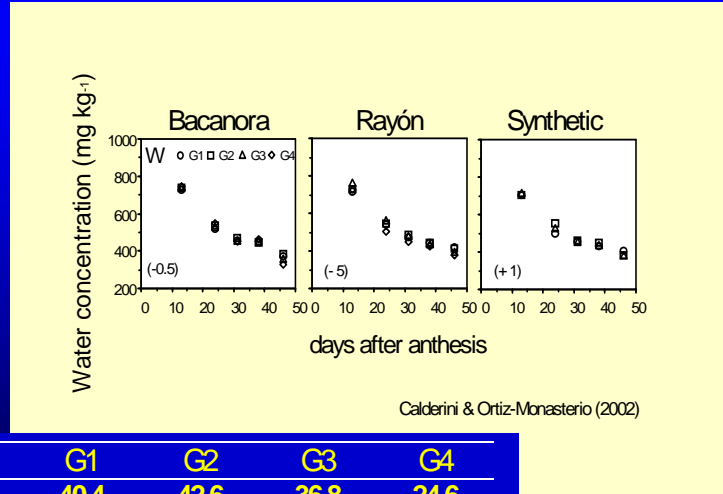


Calderini *et al.* (2000)
Agronomy Journal



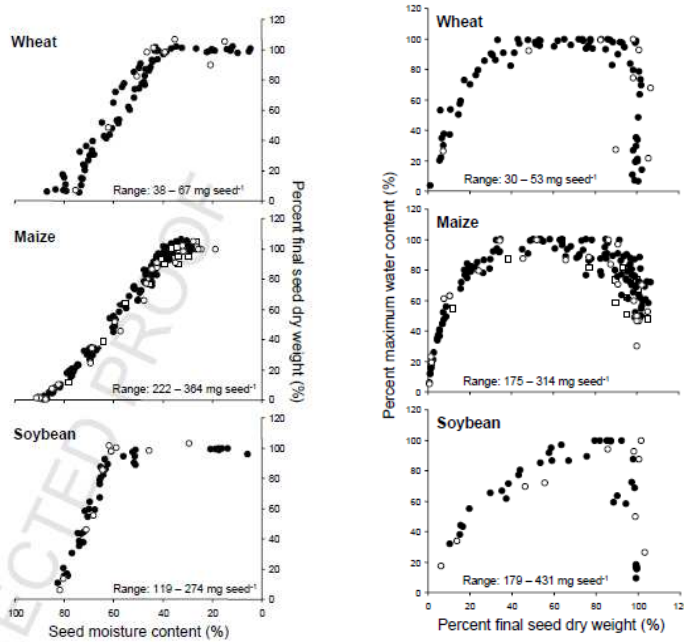
An individual spikelet 40 days after pollination. floret 2 has been cut away and its component parts are separated. The grain has started to shrink and the colour has changed to a light brown. The glumes, lemmas and palea, which have protected the grain, are now dry and brittle.

Contenido Hídrico en Diferentes Posiciones de Granos



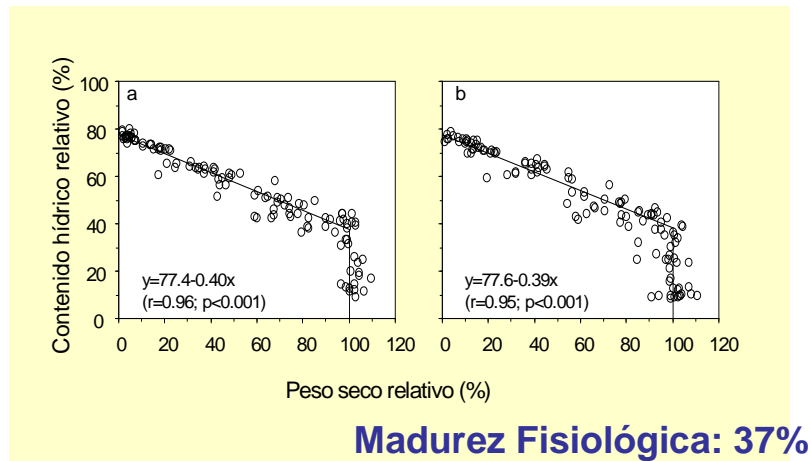
Genotipo	G1	G2	G3	G4
Bacanora	40.4	42.6	36.8	24.6
Rayón	41.1	43.3	37.0	22.2
Sintético	41.7	45.7	38.5	-

Dinámicas de Agua y Peso Seco de los Granos



Borrás et al. (2004)
Field Crops Res.

Relación entre el Contenido Hídrico y el Peso de los Granos (%)



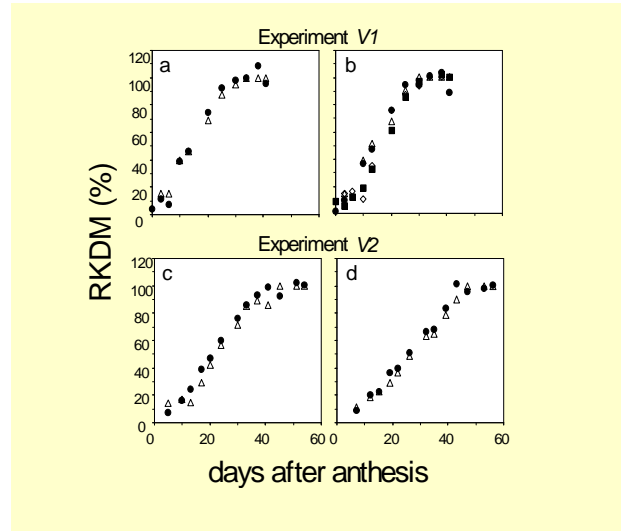
Calderini *et al.* (2000)
Agronomy Journal

Modelo de Contenido Hídrico de los Granos

$$RKDM_i = (KWC_i - 77.5) / -0.405 \quad [8]$$

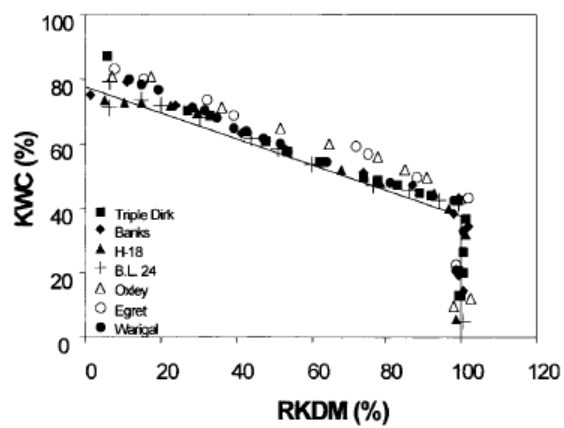
where $RKDM_i$ is relative kernel dry matter at time i relative to that at maturity (%) and KWC_i is kernel water concentration (%) at time i . The only measurement required is the determination of KWC. This value is then substituted into Eq. 8.

Validación del Modelo de Contenido Hídrico



Calderini *et al.* (2000)
Agronomy Journal

Validación del Modelo de Contenido Hídrico



Calderini *et al.* (2000)
Agronomy Journal

Importancia del Número de Células Endospermáticas

Brocklehurst (1977) mostró que existe relación entre el peso final de los granos de cebada y el número de células del endosperma

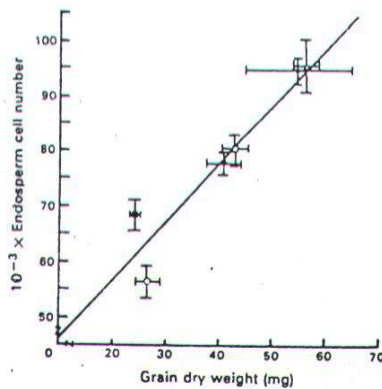
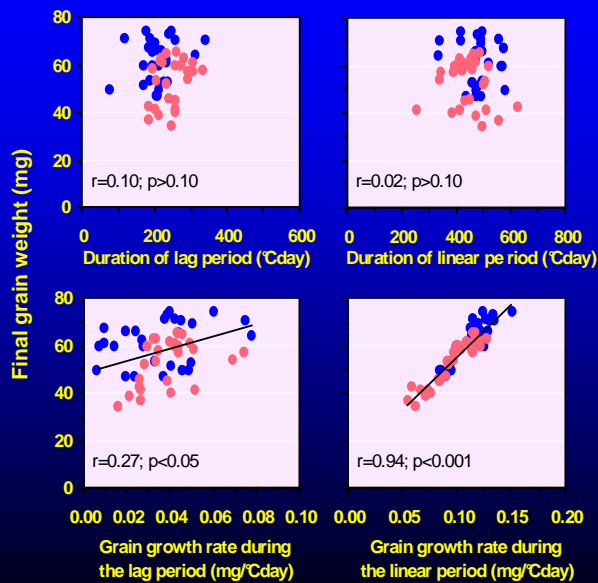


Fig. 3. Relationship between the dry weight of mature grains, calculated from the logistic model, and the maximum number of endosperm cells, calculated using the method described in the text. Confidence limits of grain dry weights ($P < 0.05$), calculated using the model, are represented by the horizontal error bars. Vertical error bars represent standard errors of the mean of endosperm cell numbers. The regression equation is $y = 35802 + 1041x$, $r^2 = 0.90$. Symbols as for Fig. 1.

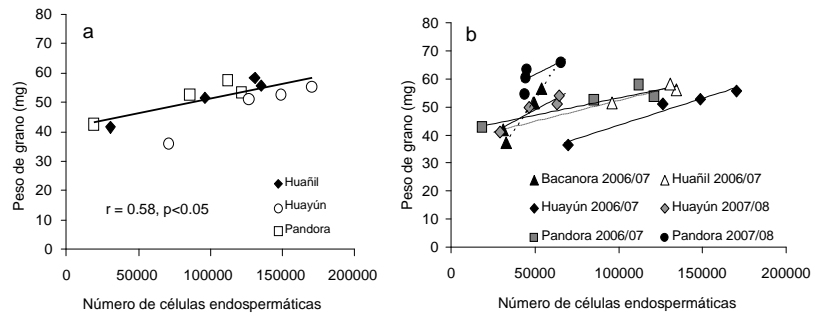
Gleadow et al. (1982)
Aust. J. Plant Physiol.

Tasa y Duración del Llenado de Grano



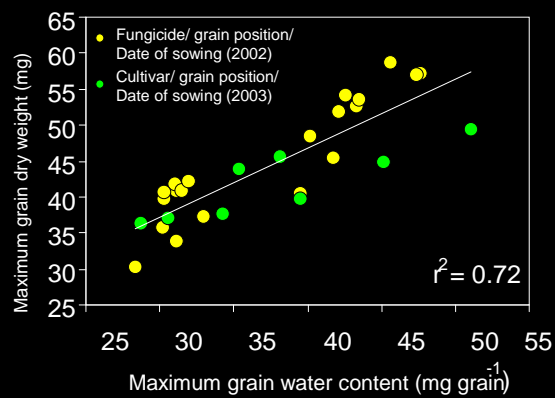
Calderini & Reynolds (2000)
Aust. J. Plant Physiol.

Peso de Grano y Células Endospermáticas



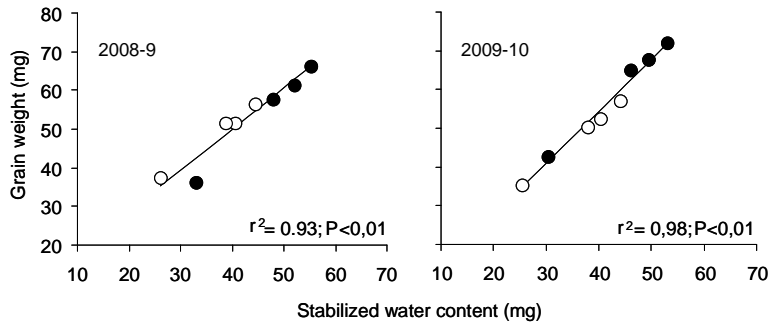
Lizana et al. (datos no publicados)

Relación entre el Peso y el Contenido Hídrico de los Granos



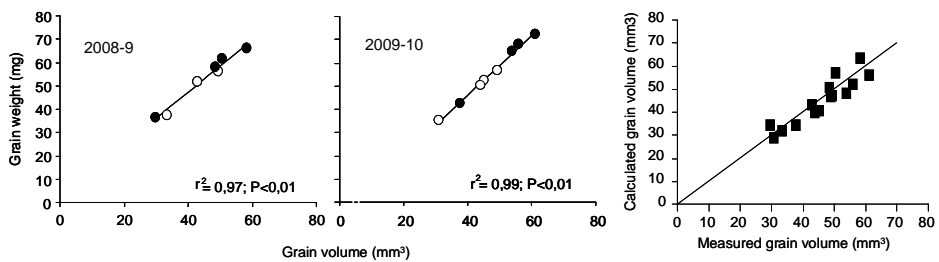
Pepler et al. (2006)
Field Crops Res.

Relación entre el Peso y el Contenido Hídrico Estabilizado de los Granos



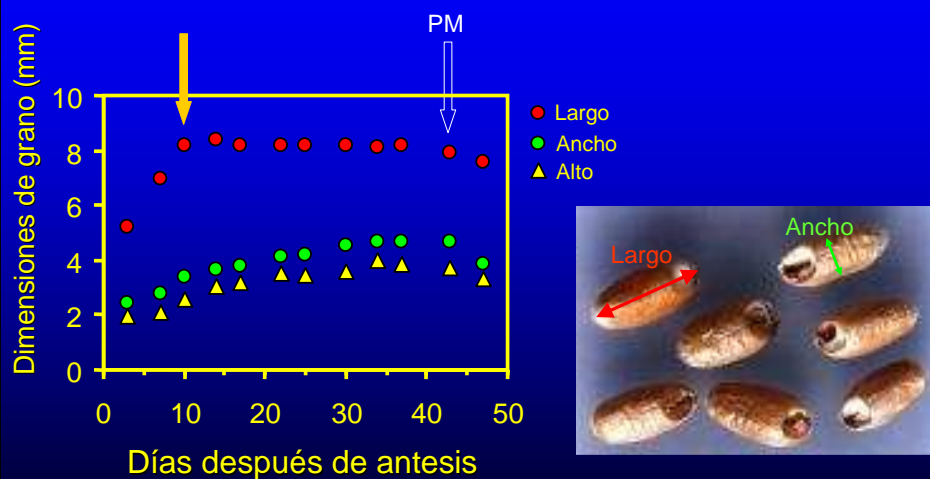
Hasan et al. (2011)
Field Crops Res.

Relación entre el Peso y el Volumen de los Granos



Hasan et al. (2011)
Field Crops Res.

Dinámica de las dimensiones de grano



Lizana et al. (2010)
Journal of Experimental Botany

Peso y Largo de Grano de Trigo

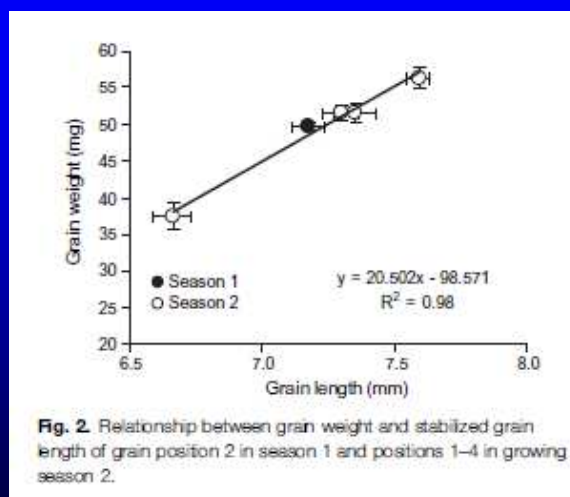


Fig. 2. Relationship between grain weight and stabilized grain length of grain position 2 in season 1 and positions 1–4 in growing season 2.

Lizana et al. (2010)
Journal of Experimental Botany

Dinámicas del Grano

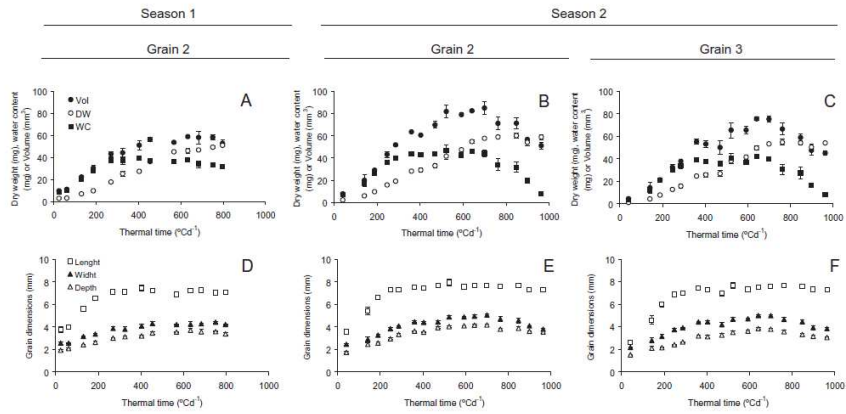


Fig. 1. Volume (filled circles), dry weight (open circles), water content (filled squares), and grain dimensions [length (open squares), width (filled triangles), and height (open triangles)] of grain position 2 in growing seasons 1 (A, D) and 2 (B, E) and grain position 3 (C, F) in season 2.

Lizana et al. (2010)
Journal of Experimental Botany

Relación entre las Dinámicas

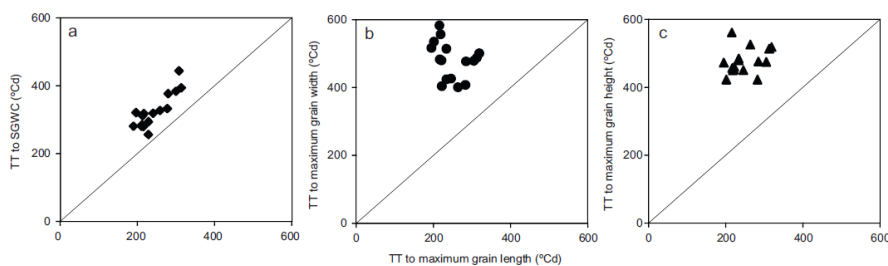


Fig. 4. Relationship between timings of (a) stabilized grain water content (SGWC), stabilized value of (b) grain width or (c) grain height and timing of maximum grain length of Bacanora and Kambara. Line shows the 1:1 ratio.

Hasan et al. (2011)
Field Crops Res.

Valores estabilizados y Duraciones del Grano

Table 3

Stabilized grain water content (SGWC), maximum grain volume (MV), grain dimensions: grain length (GL), width (GWth) and height (GHht) and thermal time (TT) after anthesis when these values were achieved in different grain positions (GP) of Bacanora and Kambara (data averaged across season).

Cultivar	GP	GL (mm)	SGWC (mg)	GWth (mm)	GHht (mm)	MV (mm ³)	TT-GL (°Cd)	TT-SGWC (°Cd)	TT-GWth (°Cd)	TT-GHht (°Cd)	TT-MV (°Cd)
Bacanora	1	7.3 d	40.3 e	4.8 d	3.6 c	73.1 f	209 d	318 de	460 bc	466 ab	569 d
	2	7.6 c	44.1 d	4.8 d	4.1 a	85.1 d	231 cd	319 de	454 bc	454 c	579 cd
	3	7.4 d	38.2 f	4.7 d	3.7 b	74.3 e	243 abc	327 de	440 c	490 ab	630 ab
	4	6.7 f	25.8 h	4.1 f	3.2 d	51.2 h	258 ab	333 cd	416 c	454 c	603 abcd
Kambara	1	8.0 b	50.8 b	5.1 a	4.0 a	94.7 b	243 abc	377 bc	506 ab	450 c	589 bcd
	2	8.3 a	54.2 a	5.0 ab	4.1 a	102.5 a	262 ab	384 b	518 a	462 c	601 abcd
	3	8.3 a	47.0 c	4.9 c	3.7 b	88.4 c	276 ab	394 b	508 ab	499 ab	620 abc
	4	7.1 e	31.6 g	4.4 e	3.5 c	66.2 g	264 a	444 a	536 a	538 a	642 a
s.e.m		0.114	1.87	0.065	0.062	3.24	5.71	7.99	9.85	9.37	6.86
Cultivar		***	***	***	***	***	***	***	***	***	***
Grain position		***	***	***	***	***	ns	ns	ns	ns	ns
Cv × GP		**	*	ns	ns	ns	ns	ns	ns	ns	ns

s.e.m. stands for the standard error of the means. Different letters within the same column indicate statistically significant differences at $P < 0.05$. Values are means of three replicates.

ns means not significant effects.

* Significant effects by cultivar (Cv), grain position (GP) or their interaction at $P < 0.05$.

** Significant effects by cultivar (Cv), grain position (GP) or their interaction at $P < 0.01$.

*** Significant effects by cultivar (Cv), grain position (GP) or their interaction at $P < 0.001$.

Hasan *et al.* (2011)
Field Crops Res.



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METRICE

Mejorar la eficiencia en el uso de insumos y el ajuste fenológico en cultivos de trigo y cebada

Universidad Autónoma del Estado de México



Crecimiento de los Granos: Efecto del Estrés



Daniel F. Calderini
Universidad Austral de Chile



Toluca, septiembre de 2011

¿Limitación por fuente de asimilados durante el llenado de granos?

Relación Fuente:Destino post-antesis en trigo

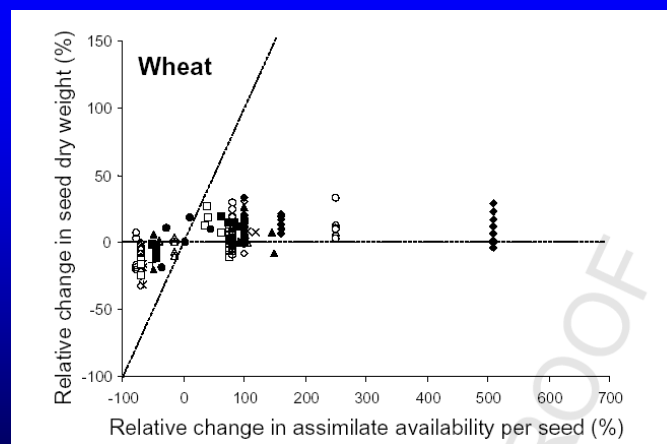


Fig. 2. Relationship between wheat relative change in seed dry weight and the relative change in potential assimilate availability per seed produced during seed-filling in a number of experiments. Dashed lines stand for the theoretical slopes of 1 (full source limitation) and 0 (full sink limitation).

Borrás et al. (2004)

Relación Fuente:Destino post-antesis en maíz

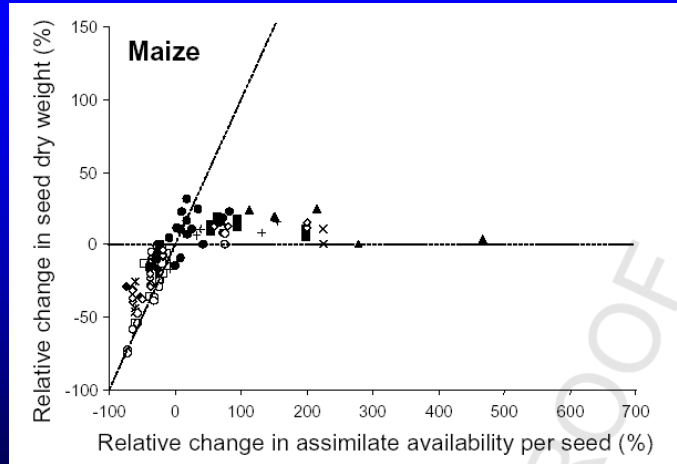


Fig. 3. Relationship between maize relative change in seed dry weight and the relative change in potential assimilate availability per seed produced during seed-filling in a number of experiments. Dashed lines stand for the theoretical slopes of 1 (full source limitation) and 0 (full sink limitation).

Borrás et al. (2004)

Relación Fuente:Destino en Ambientes Mediterráneos

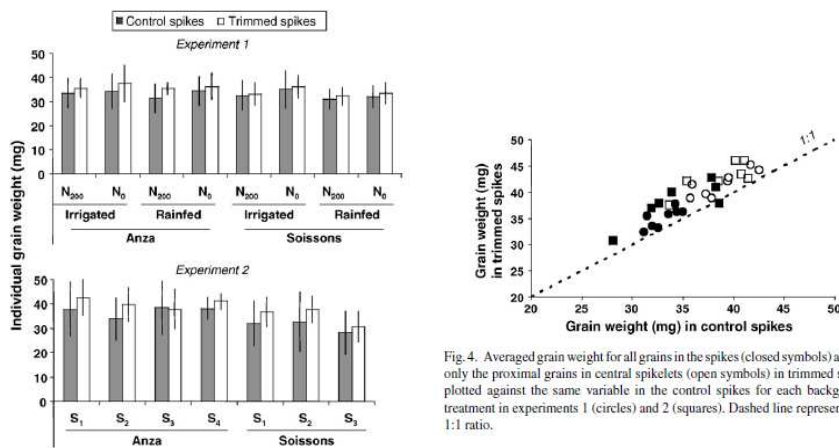


Fig. 4. Averaged grain weight for all grains in the spikes (closed symbols) and for only the proximal grains in central spikelets (open symbols) in trimmed spikes plotted against the same variable in the control spikes for each background treatment in experiments 1 (circles) and 2 (squares). Dashed line represents the 1:1 ratio.

Cartelle et al. (2006)
Field Crops Research

Relación Fuente:Destino en Trigo: Impacto de alta restricción de fuente

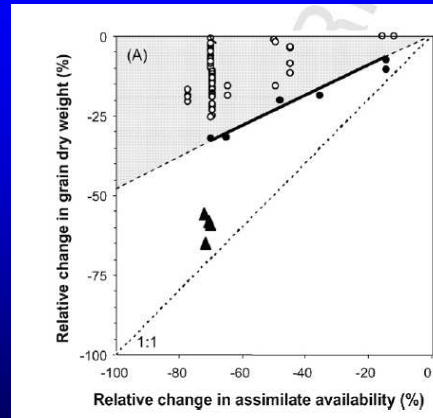
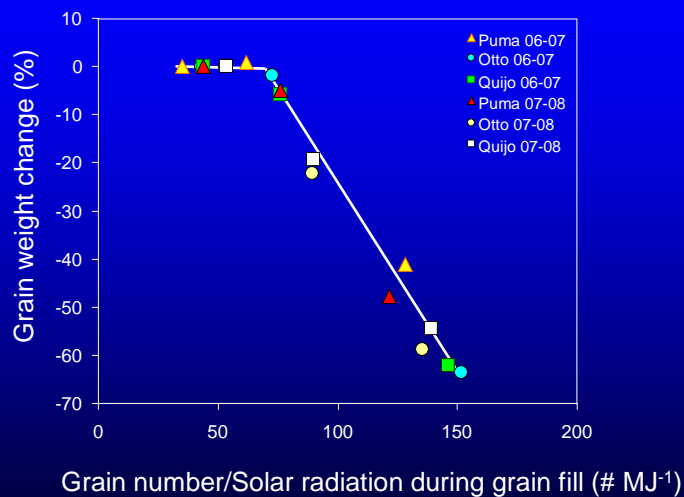


Fig. 6. Relationship between relative change of grain weight and relative change of assimilate availability during grain filling of wheat (A, closed triangles), lupin (B, closed squares) and pea (B, open triangles) in response to shading treatments recorded in the present study and previous studies reviewed by Borrás et al. (2004). Data from previous studies correspond to wheat (A, open circles) and soybean (B, open squares). Shaded areas show the range of data explored in previous studies. Closed circles were used to fit solid lines.

Sandaña, Harcha & Calderini (2009)
Field Crops Research

Grain weight response to source-sink ratios



Amador & Calderini (unpublished)

Relaciones Fuente:Destino en Diferentes Momentos del Llenado

Exp.	Cultivar	S-S ratio	Grain filling period					
			Wheat			Lupin		
			Treatment	Incident	Duration	Duration	Incident	Radiation
			days	°Cd	MJ m ⁻²	days	°Cd	MJ m ⁻²
Exp. 1	Ot/Qu	C	52	770	578	78	1249	858
		Sh _{All}	39	646	180	50	830	338
	Hu/Be	C	37	598	405	67	1064	717
		Sh _{All}	24	396	170	42	682	294
Exp. 2	Ot/Qu	C	46	798	553	68	1142	811
		Sh _{All}	36	617	176	48	836	287
		Sh _{1st}	18	299	380	21	364	582
		Sh _{2nd}	18	318	349	27	472	516
	Hu/Be	C	42	730	507	68	1142	811
		Sh _{All}	31	527	184	52	909	247
		Sh _{1st}	18	296	332	22	387	559
		Sh _{2nd}	13	231	359	30	522	508

Harcha & Calderini (unpublished)

Relaciones Fuente:Destino en Diferentes Momentos del Llenado Peso de Grano

Exp	S-S ratio	Grain weight (mg, %)							
		Wheat				Lupin			
		Otto	Huayun	Quilnock	Belara				
Exp. 1	C	46.8	54.5	185.3	153.8				
	Sh _{All}	15.1	-67.8	27.2	-50.1	13.2	-92.9	70.2	-54.5
	s.e.m. [†]	0.68		5.18					
	Cv	***		*					
	S	***		***					
	Cv x S	*		***					
	Exp. 2	C	44.0	42.8	182.4	168.3			
Sh _{All}	17.0	-61.3	19.6	-54.2	17.8	-90.3	28.3	-83.2	
Sh _{1st}	21.6	-50.8	24.1	-42.8	18.2	-90.0	127.7	-24.1	
Sh _{2nd}	36.6	-16.9	37.3	-13.0	130.7	-28.3	123.1	-26.8	
s.e.m. [†]	1.19		3.69						
Cv	n.s.			***					
S	***			***					
Cv x S	n.s.			***					

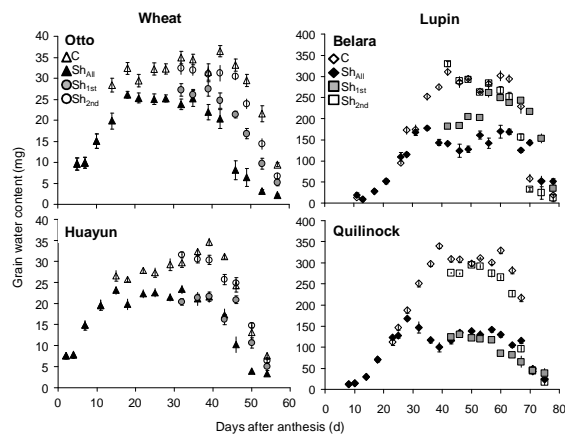
Harcha & Calderini (unpublished)

Relaciones Fuente:Destino en Diferentes Momentos del Llenado Contenido Hídrico

Exp	S-S ratio	Stabilized grain water content (mg, %)							
		Wheat		Lupin					
		Otto	Huayun	Quillinock	Belara				
Exp. 1	C	33.9	42.7	319.4	343.3				
	Sh _{All}	24.3	-28.3	28.9	-32.3	114.6	-64.1	184.9	-46.1
	s.e.m. [†]	1.18		9.44					
	Cv	**		**					
	S	***		***					
	Cv x S	n.s.		n.s.					
Exp. 2	C	31.2	28.5	311.2	289.7				
	Sh _{All}	22.1	-29.1	20.5	-28.1	141.6	-54.5	152.8	-47.3
	Sh _{1st}	22.7	-27.1	19.6	-31.0	132.1	-57.6	259.7	-10.4
	Sh _{2nd}	29.0	-7.1	27.8	-2.5	292.4	-6.0	281.7	-2.8
	s.e.m. [†]	0.64		6.56					
	Cv	***		***					
	S	***		***					
	Cv x S	n.s.		***					

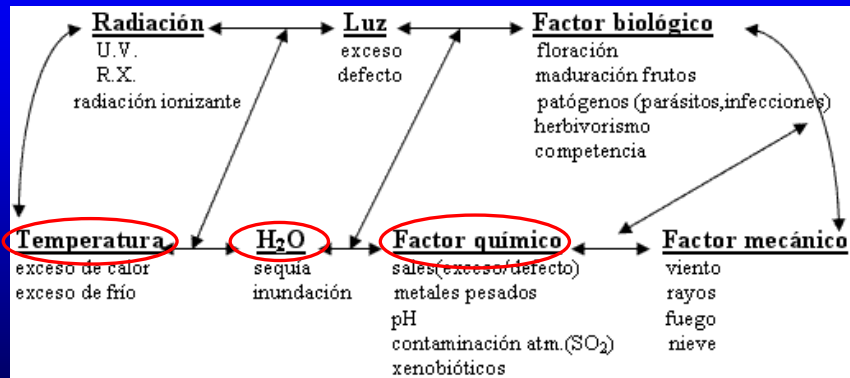
Harcha & Calderini (unpublished)

Relaciones Fuente:Destino en Diferentes Momentos del Llenado Dinámica del Contenido Hídrico



Harcha & Calderini (unpublished)

Factores de estrés en plantas y sus interrelaciones



Fuente: <http://www.elergonomista.com>

Estrés térmico durante el llenado

Efecto Térmico

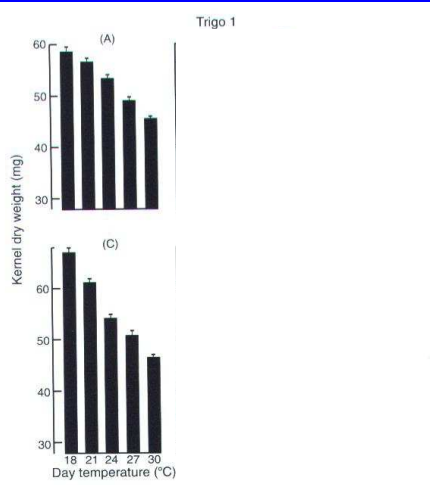
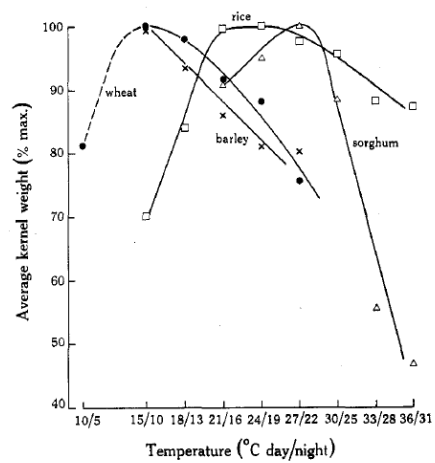


Fig. 1. The effect of high temperature treatments during kernel development on kernel weight at maturity of two wheat cultivars, (A) Trigo 1: chronic heat stress, (B) Trigo 1: heat shock, (C) Lyallpur: chronic heat stress, (D) Lyallpur: heat shock. The dashed lines across B and D indicate the kernel dry weight of the 21/16°C controls for the heat-shock treatments. Each value is the mean of 21 replicates, with s.e. shown as a vertical bar.

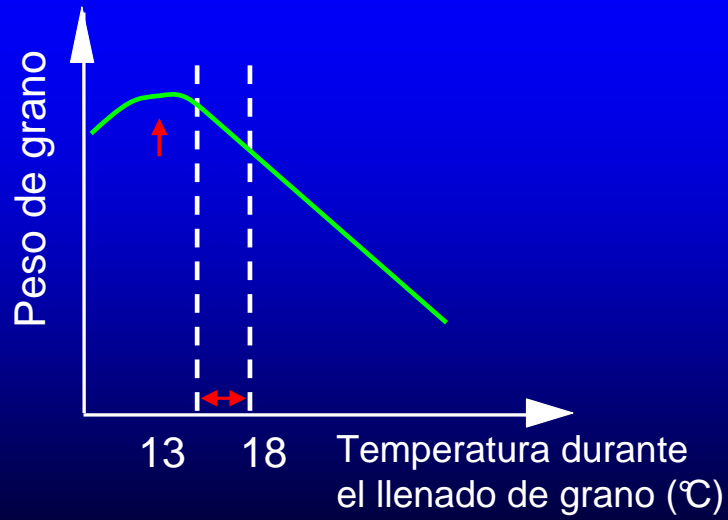
Wardlaw et al. (2002)

Respuesta del Peso de Grano a la Temperatura



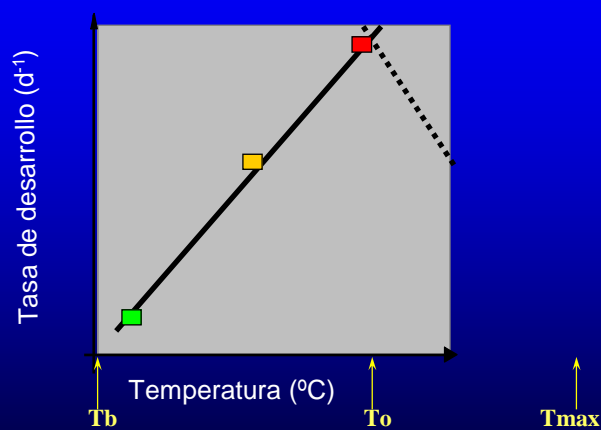
Chowdhury & Wardlaw (1978)
Aust. J. Agric. Res.

Efecto de la temperatura sobre el peso de grano



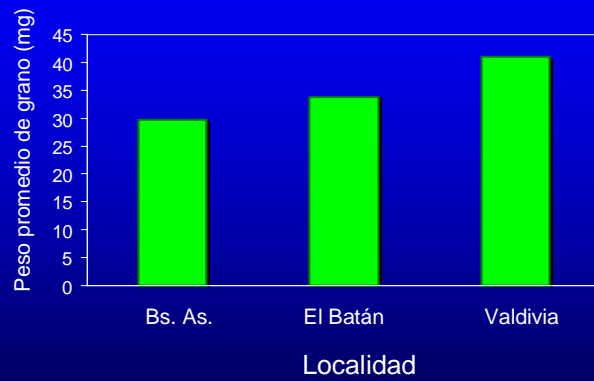
*Adaptado de Chowdhury & Wardlaw (1978)
Australian Journal of Agricultural Research*

Tasa de desarrollo y temperaturas cardinales



Slafer (2004)

Peso promedio de grano (cv. Bacanora) en diferentes localidades



La temperatura durante el llenado de granos

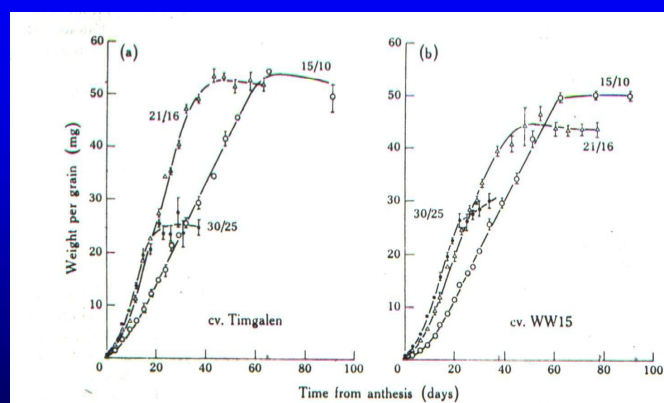
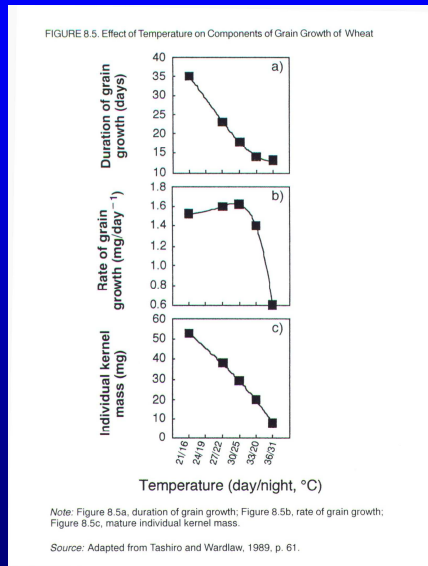


Fig. 1. Increase in dry weight of wheat grains as influenced by temperature after anthesis in experiment II: (a) first floret grains in the middle four spikelets of cv. Timgalen; (b) first floret grains in the middle four spikelets of cv. WW15. Vertical bars indicate the standard errors of the mean.

Sofield *et al.* (1977)

Efecto térmico sobre la tasa y duración del llenado de granos

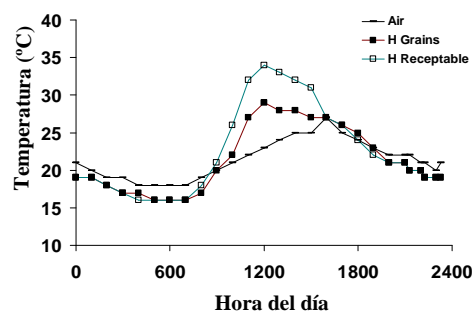


Stone (2001)

Adaptado de Tashiro & Wardlaw (1989)

Temperatura de los órganos

Raíces, hojas, ápices, flores, granos: pueden tener temperaturas diferentes de la temperatura del aire



Ploschuk & Hal (1995)

Field Crops Res.

Temperatura del canopeo

248

P.V.V. Prasad et al. / *Agricultural and Forest Meteorology* 139 (2006) 237–251

Sorgo en
cámara
con
elevado
CO₂

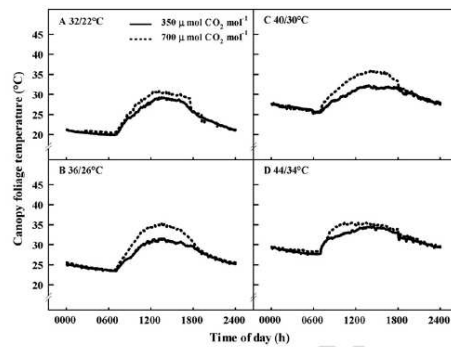


Fig. 10. Measured canopy foliage temperature (°C) during 24 h period under ambient and elevated CO₂ at different temperatures treatments (A) 32/22 °C; (B) 36/26 °C; (C) 40/30 °C; and (D) 44/34 °C. Data are the mean of 60 days period (35–95 DAS) when canopy was fully developed and covered the chamber.

Prasad et al. (2006) AFM

Condiciones de estrés hídrico y alta concentración de CO₂ pueden aumentar la temperatura de los órganos (por disminución de la conductancia)

Estrés térmico por breves períodos

El shock térmico

Temperaturas durante el llenado de granos

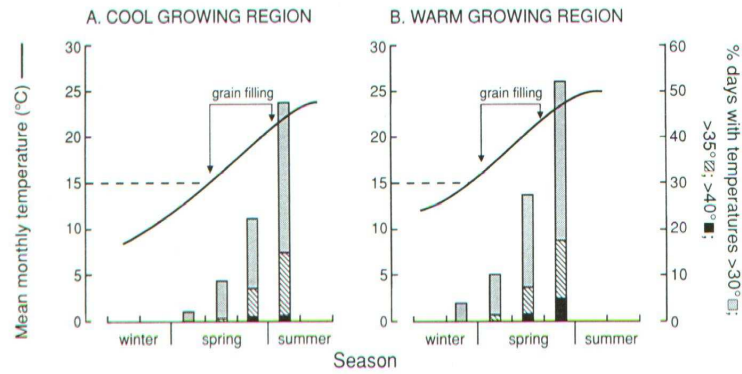


Fig. 1. Changes in mean monthly temperatures during grain filling and the frequency of high maximum day temperatures during that period. Two cereal growing regions in Australia have been selected to represent a cool (A) and a warm (B) region. The Spring period for Australia includes the whole of each of the months September, October and November.

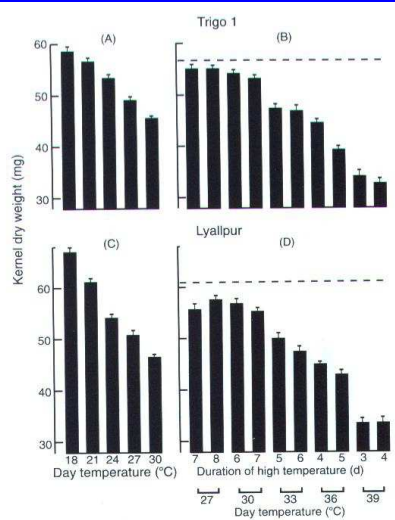


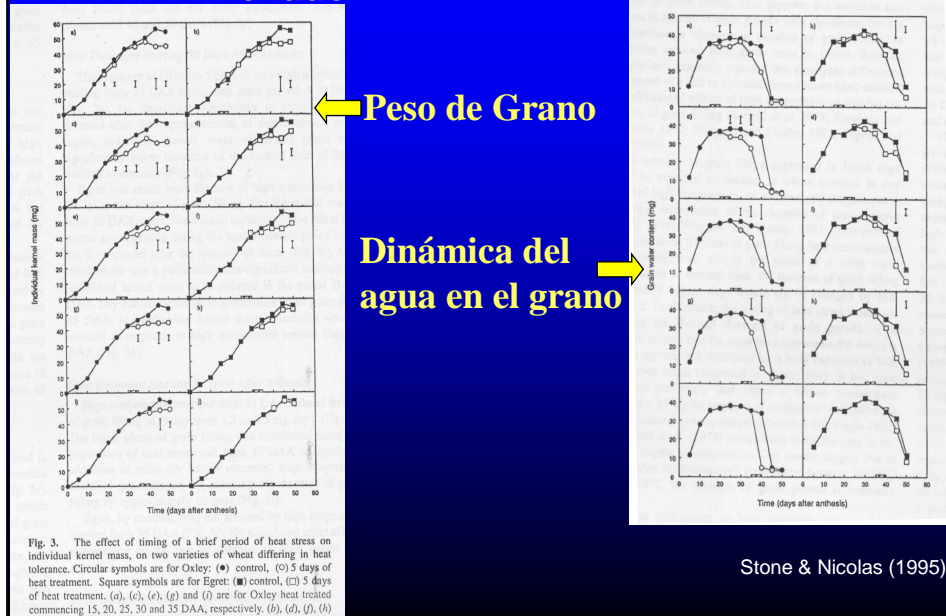
Fig. 1. The effect of high temperature treatments during kernel development on kernel weight at maturity of two wheat cultivars. (A) Trigo 1: chronic heat stress, (B) Trigo 1: heat shock, (C) Lyallpur: chronic heat stress, (D) Lyallpur: heat shock. The dashed lines across B and D indicate the kernel dry weight of the 21/16°C controls for the heat-shock treatments. Each value is the mean of 21 replicates, with s.e. shown as a vertical bar.

Efecto Térmico

Wardlaw et al. (2002)

Breves períodos de altas temperaturas durante el llenado

“Heat Shock Effect”



Concepto de carga calórica

Table 1. Temperature treatments during kernel filling

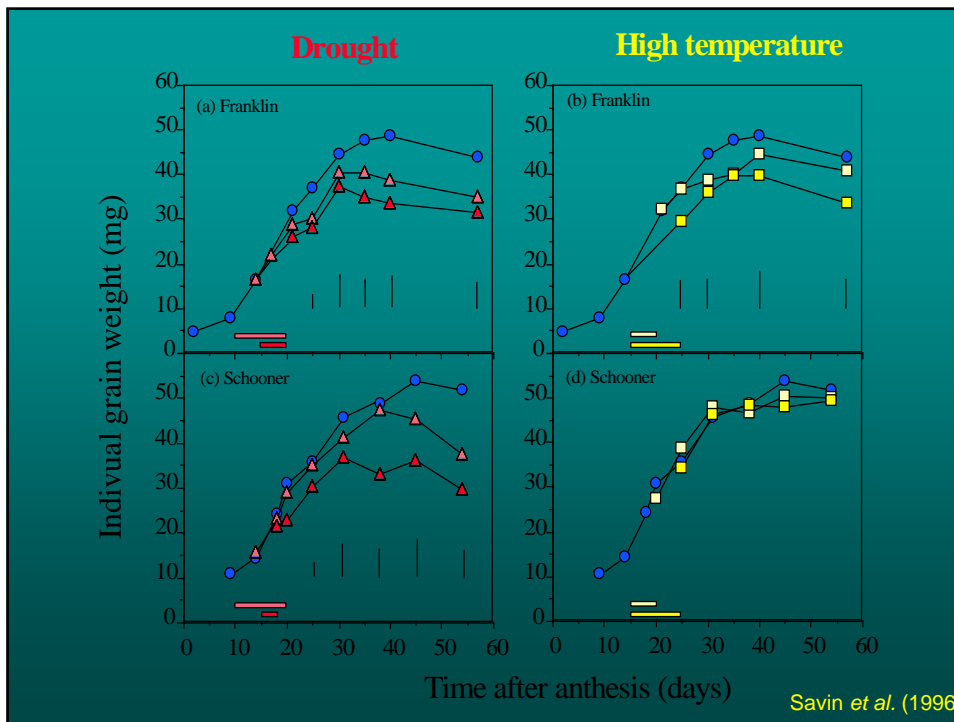
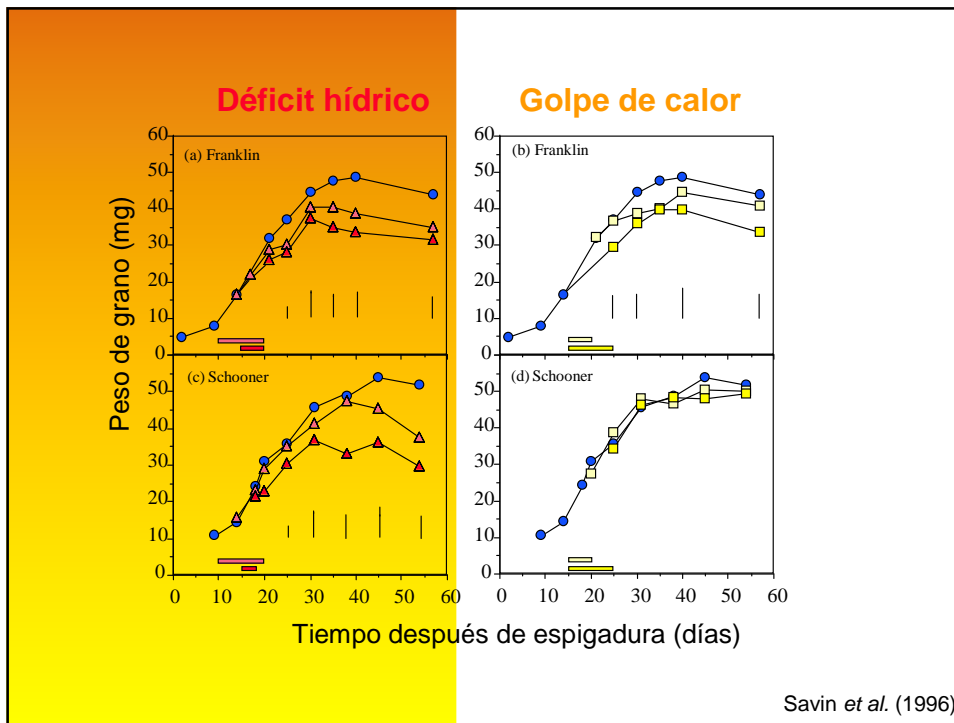
(A) Chronic high temperature (treatments throughout kernel filling)

Day/night temperature (°C; 8/16 h)	Mean temperature (°C)	Duration of kernel filling (d)	Estimated heat sum (°C-d)
18/13	14.7	41	398
21/16	17.7	32	406
24/19	20.7	25	393
27/22	23.7	20	374
30/25	26.7	16	347

(B) Acute heat shock (treatments for short periods commencing 20 d after anthesis)

Day/night temperature (°C; 8/16 h)	Mean temperature (°C)	Duration of treatment (d)	Heat load (°C-d; above base of 21/16°C)
27/22	23.7	7	42
30/25	26.7	6	48
		7	63
33/28	29.7	5	60
		6	72
36/31	32.7	4	60
		5	75
39/34	35.7	3	54
		4	72

Wardlaw et al. (2002)



Estrés Hídrico

Peso de Grano

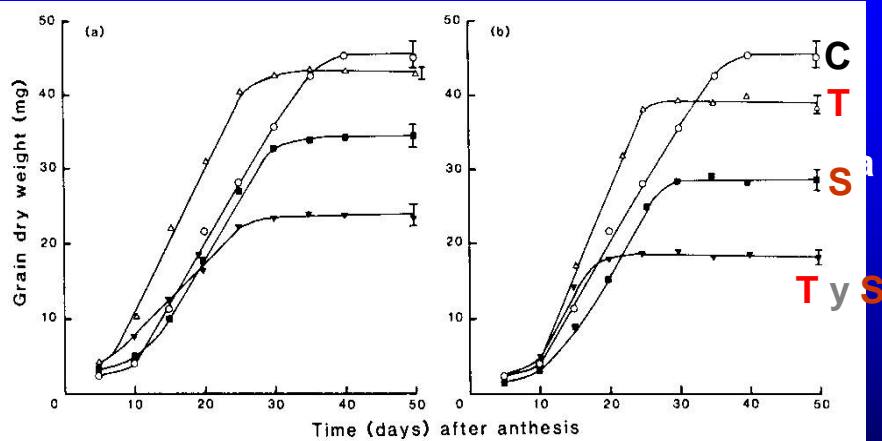
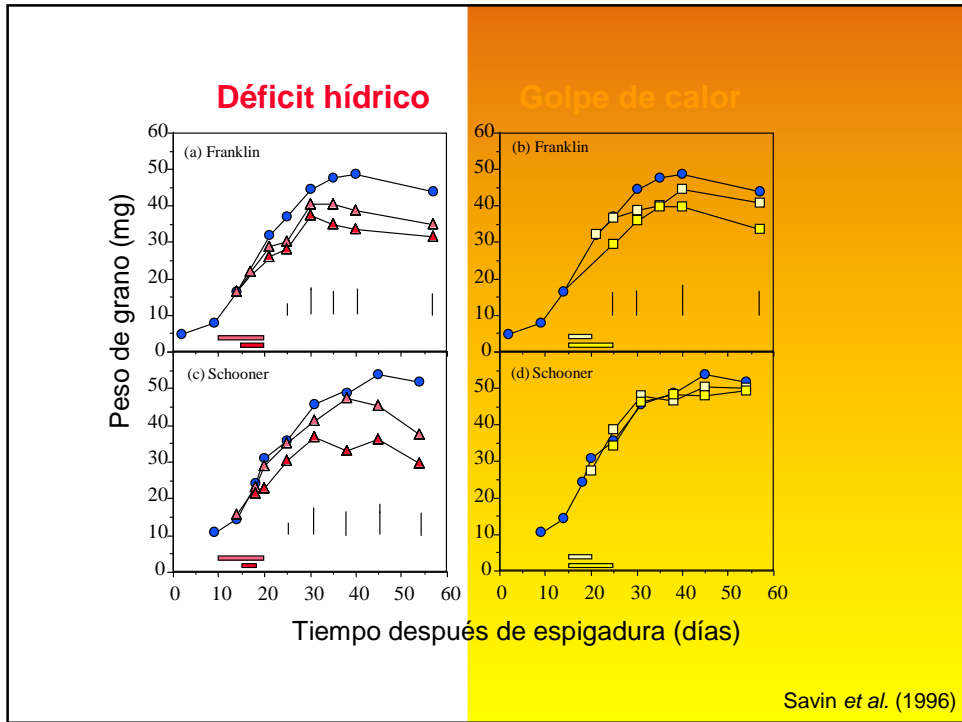
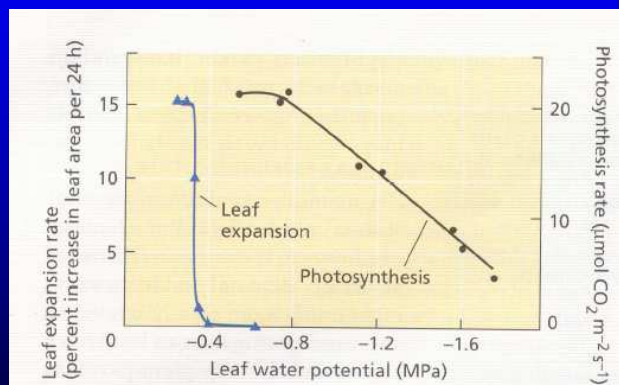


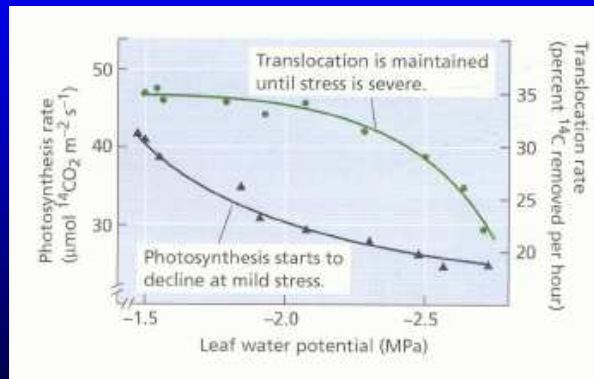
Fig. 2. Grain dry weight of plants subjected to treatments during the early period (a) and late period (b) of cell division. Curves were fitted using a logistic model. \circ Control. Δ High temperature. \blacksquare Drought. \blacktriangledown Drought \times high temperature. Error bars, representing confidence limits ($P = 0.05$) of the asymptotic weight, K , were calculated using the model.



Efecto del Estrés Hídrico sobre la Expansión Foliar y la Fotosíntesis



Efecto del Estrés Hídrico sobre la Fotosíntesis y la Translocación de Fotoasimilados



Sensibilidad de la elongación foliar y la fotosíntesis

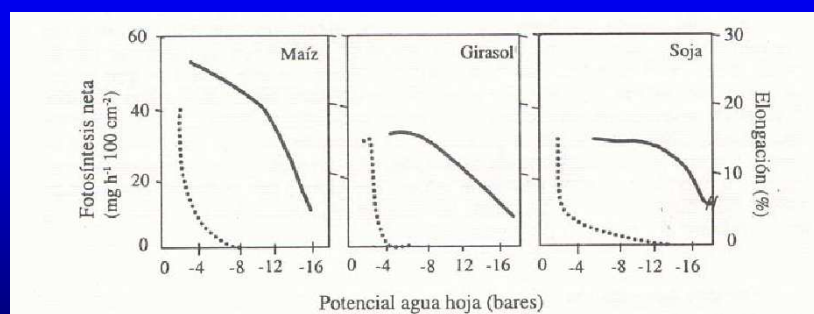
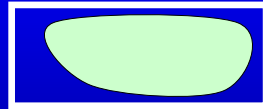


Figura 16.20. Sensibilidad de la elongación foliar (línea punteada) y la fotosíntesis neta (línea llena) al déficit hídrico en maíz, girasol y soja. Adaptado de Boyer (10).

Estrés Hídrico

Respuestas del crecimiento celular y la expansión foliar



$$\Psi_a = \Psi_o + \Psi_p$$

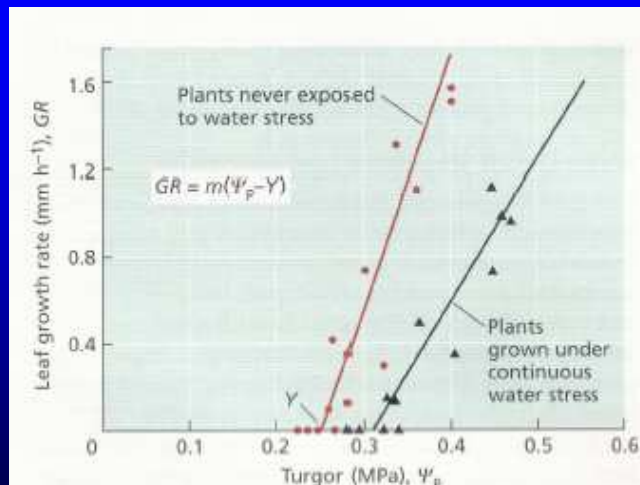
Desecación celular

Expansión celular:

$$TC \text{ (m}^3 \text{ s}^{-1}\text{)} = m (\Psi_p - Y)$$

TC: tasa de crecimiento; m: extensibilidad de la pared; Y: umbral de crecimiento (presión mínima necesaria para extender la pared)

Tasa de Expansión Foliar con y sin Estrés Hídrico



El estrés también modifica m y Y

m : por incremento del pH celular

Y : ¿por cambios estructurales de la pared?

